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Tensile Properties and Strain Response of Cu-Al Bi-Metal Tube

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ABSTRACT

Background: Recent high price of copper in global market forced the heat, ventilation, and air condition (HVAC) industry players to find alternative materials with relatively lower market price compared to copper such as aluminum for replacement. **Objectives:** This study characterizes tensile properties and strain response of new Cu-Al bi-metal tubes i.e. aluminum cladded copper (ACC) and copper cladded aluminum (CCA) in order to look at the possibility of applying the bi-metal tubes in HVAC industries. **Results:** Tensile properties of CCA and ACC bi-metal tubes are different and depend on cladded materials. **Conclusion:** Tensile properties of CCA tubes was higher than that of ACC bi-metal tubes in two different strain rates of 1×10^{-3} and 1×10^{-1} sec $^{-1}$. Also, Strain response refers to the sample elongation at break shows a higher elongation value of CCA samples compared to ACC.

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INTRODUCTION

Copper is very well known material with excellent properties for conducting heat and electricity. It also demonstrates very good mechanical and corrosion-resistant properties which lead to the widely use of these metals in electrical and electronic industry, heat exchangers, cooling, plumbing etc. (Karamış, M.B., 2001; Gueydan, A., 2014).

However, the increasing of copper price of about 20-25% in global market has forced the industry players to find alternative materials for replacing copper. Aluminum is one of the highlighted materials because of a light weight metal with relatively lower market price compared to copper (Khosravifard, A. and R. Ebrahimi, 2010).

A new product of bi-metal tube consists of copper and aluminum with metallurgical bonding has given an alternative to the industry as the usage of copper in a bi-metal tube is only 30% which is caused low mass and the remaining material is replaced by aluminum which relatively low in cost (Kang, C.G., 2002; Kim, I.K. and S.I. Hong, 2013). There are only few studies by Liou & Zhao (2001), Paramsothy *et al.* (2008), Baghdadi *et al.* (2013), and Sajuri *et al.* (2014) have been reported on the tensile properties of bi-metal materials. However, there is no study reported on the strain response of Cu-Al bi-metal tubes during tensile testing.

Therefore, this study aims to investigate the tensile properties and strain response of Cu-Al tubes i.e. copper cladded aluminum (CCA) and aluminum cladded copper (ACC) tubes in order to evaluate the possibility of implementing the bi-metal tubes in heating, ventilation, and air conditioning (HVAC) industry.

Experimental Procedures:

The material used in this study was Cu-Al bi-metal tubes i.e. ACC and CCA of 12.7 mm in diameter. Tensile test was performed on tube samples with a specimen length of 70 mm under two different strain rates of 1×10^{-1} and 1×10^{-3} sec $^{-1}$. Tensile samples were cut from tubes by using EDM wire cutting machine.

Fig. 1 shows machined samples and its dimension. To avoid the sample to become dent at the gripping position during test, an insert plug was inserted into both ends of the tube sample (Fig. 2). Tensile test was performed on a Zwick-Roell universal testing machine with capacity of 100kN. Two KYOWA strain gauges with gage length of 2mm were mounted on the Al and Cu surfaces to measure strain response of each surface during tensile loading.

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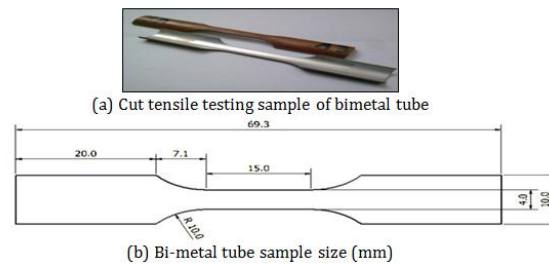


Fig. 1: Tensile testing sample of bimetal tube.

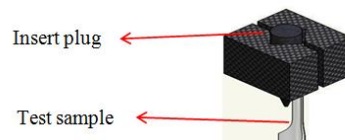


Fig. 2: Test sample gripping configuration.

RESULT AND DISCUSSION

1.1. Tensile test:

Two different strain rates were applied to the samples test to identify the tensile properties and strain response. Strain rates used in this test were 1×10^{-3} and 1×10^{-1} sec $^{-1}$. Table 1 shows the results of tensile test samples of CCA and ACC with two different strain rates. The CCA at strain rate of 1×10^{-3} sec $^{-1}$ showed an elastic modulus of 55 GPa, yield stress of 106 MPa, ultimate stress of 150 MPa and elongation of 35%; tensile of CCA at higher strain rate of 1×10^{-1} sec $^{-1}$ resulted similar tensile properties with that of 1×10^{-3} sec $^{-1}$.

Table 1: Tensile properties of ACC and CCA in different strain rates

Strain Rate (S-1)	Sample	Elasticity Modulus (GPa)	Yield Stress (MPa)	Ultimate Stress (MPa)	Elongation (%)
10-3	CCA	55	106	150	35
	ACC	50	101	131	26
10-1	CCA	55	113	168	36
	ACC	54	94	138	32

However, differences were observed on the tensile properties of ACC and CCA samples. Tensile properties of CCA samples were higher than the ACC samples of the same strain rate. This is believed due to the higher thickness ratio of Cu/Al in CCA sample compared to that of Cu/Al ratio in ACC. Further, the higher strain rate resulted in higher tensile properties.

1.2. Strain response:

In the tensile test, strain gages bonded to Al and Cu layers of each sample. It aims to see the strain response of both these metals in Cu-Al bimetallic tube. Strain response of both the metal layer can be observed in the graph of strain versus time in Fig. 3 & 4.

Strain responses of Al and Cu versus time for CCA sample in the strain rate of 1×10^{-3} sec $^{-1}$ are shown in Fig. 3(a). The strain response of Cu was higher than Al. However, Cu strain suddenly declined at 80 seconds. This happened because the thin Cu layer was separated from the Al layer and broke. Fig. 3(b) presents the strain response of ACC sample at the same strain rate. The Al strain response started to decline at 65 seconds because of breaking of Al layer. Strain response of bi-metal tube in strain rate of 1×10^{-3} sec $^{-1}$ more clearly showed that the strain response of Cu is higher than Al in the same period for each sample to the linear region of the elastic state.

In the tensile test with strain rate of 1×10^{-1} sec $^{-1}$, the reaction of Cu layer was higher than Al layer for sample CCA as seen in Fig. 4(a). However, strain response of Al layer was higher than Cu in ACC as shown in Fig. 4(b). The strain of Cu decreased after time passed 1.0 seconds. Initial decrease was due to breaking of Cu layer before the Al layer.

Conclusion:

Tensile properties and strain response of Cu-Al tubes i.e. copper clad aluminum (CCA) and aluminum clad copper (ACC) tubes were investigated. Based on the tensile test results, it was observed that the tensile properties of the CCA were higher than ACC in both strain rates of 1×10^{-1} and 1×10^{-3} sec $^{-1}$. In addition, the

higher strain rate obtained the higher tensile properties. Also, strain response of copper layer was higher than aluminum either CCA or ACC samples for strain rate $1 \times 10^{-3} \text{ s}^{-1}$.

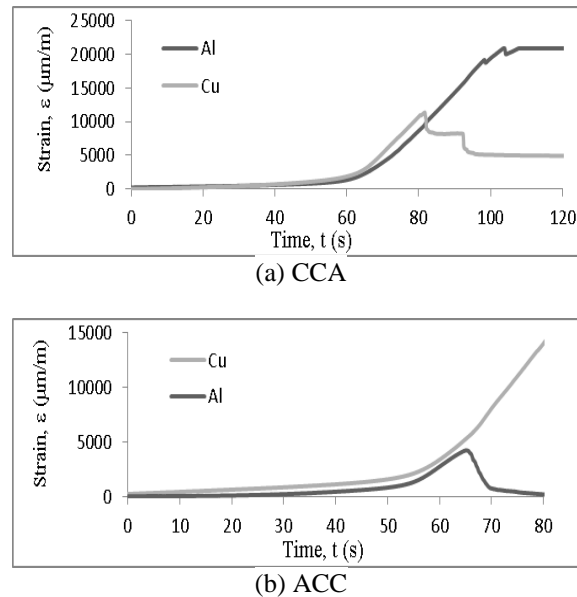


Fig. 3: Strain responses of CCA and ACC at $1 \times 10^{-3} \text{ sec}^{-1}$.

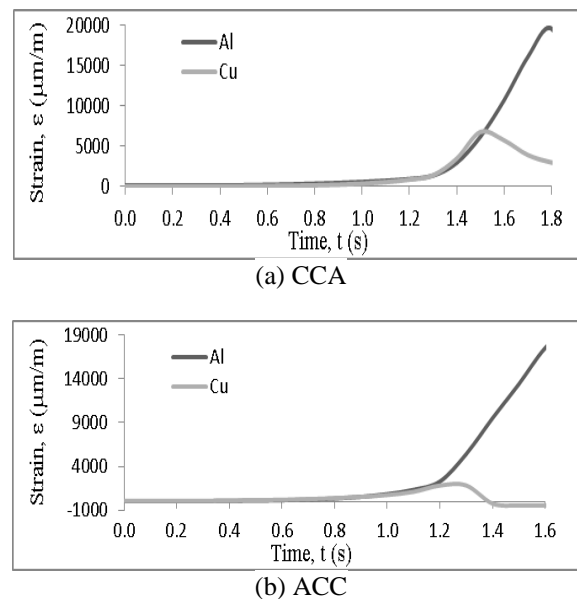


Fig. 4: Strain responses of CCA and ACC at $1 \times 10^{-1} \text{ sec}^{-1}$

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